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Comparison of training load during competitive league games and sessions of different small-sided soccer games in youth soccer players

Liigamängude ja jalgpallitrenni erinevate vähendatud mängijate arvu ning väljaku mõõtmetega mängude treeningkoormuse võrdlus noorjalgpallurite näitel

Master's Thesis

Physical education and sport

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CONTENTS

ABSTRACT

Aim: The aim of the present master's thesis was to investigate training load during competitive soccer matches and different small-sided games (SSG) played in soccer trainings. Secondly, we aimed to study the interaction of endurance performance to the measured training load parameters during competitive matches in youth soccer players.

Methods: 19 Estonian second division male soccer players (age: 17.6±1.1 yrs; body mass: 74.1±8.6 kg; body height 182.4±7.4 cm) participated in the present study. Players performed Yo-Yo Intermittent Recovery Test Level 1 (YY test) as general soccer fitness test, 4 trainings of 5 versus 5 (5v5) (field: 48x31 m, duration: 5x5 min), 4 trainings of 8 versus 8 (8v8) (field: 76x49 m, duration: 3x10 min) SSG-s and 5 competitive 11 versus 11 (11v11) soccer matches. Different variables of training load were collected with time-motion equipment (accelerometer and GPS-system) and heart rate belts: accelerations (>2 m/s^2), sprint distance (>21.0 km/h), player load, heart rate in zone 90-100% of maximum and worst case scenarios (WCS) (total distance and player load).

Results: Average training load per minute was in a descending order of 5v5 > 8v8 > 11v11. Distance covered at >21.0 km/h per minute during 11v11 games (first half: 4.4±2.5 m; second: 4.7±2.5 m) was significantly higher ($p<0.05$) than during 5v5 SSG-s (3.3±3.0 m). WCS-s during SSG-s mostly did not simulate the external load of WCS of 11v11 matches. Players who were categorized into the highest performance group based on the YY test, had higher external and lower internal load during competitive matches than players in the low performance group.

Conclusion: Training load during SSG-s mostly created higher average demands than competitive games, but generally did not simulate WCS-s of a competitive match. Players who performed better during YY test, achieved higher external load and perceived less internal load during 11v11 matches.

Keywords: soccer, small-sided games, training load, time-motion analysis, heart rate

LÜHIÜLEVAADE

Eesmärk: Käesoleva magistritöö eesmärk oli hinnata treeningkoormust jalgpalli võistlusmängude ja trennis mängitavate erineva suurusega jalgpalli väikeste mängude ajal. Lisaks analüüsida vastupidavusliku taseme seost treeningkoormuse näitajatega võistlusmängu ajal noorjalgpallurite näitel.

Metoodika: Uuringus osales 19 Eesti teise divisioni meessoost jalgpallurit (vanus: 17,6±1,1 a; kehamass: 74,1±8,6 kg; keha pikkus 182,4±7,4 cm). Mängijad sooritasid vastupidavustesti *Yo-Yo Intermittent Recovery Test Level 1* (YY test), jalgpalli vähendatud mängijate arvu ning väljaku mõõtmetega mänge (VM) 5 versus 5 (5v5) (neli treeningut, väljaku suurus: 48x31 m, kestvus 5x5 min) ja 8 versus 8 (8v8) (neli treeningut, väljaku suurus: 76x49 m, kestvus 3x10 min) ning viis jalgpalli võistlusmängu 11 versus 11 (11v11) formaadis. Koguti andmed järgnevate treeningkoormuse parameetrite kohta: kiirendused (>2 m/s^2), sprintides läbitud distans (>21,0 km/h), mängu üldine koormus, südamelöögisagedus tsoonis 90-100% maksimaalsest ja mängu kõige intensiivsemad perioodid (MIP) (kogu läbitud distants, mängu üldine koormus). Mõõtmiste teostamiseks kasutati välist koormust mõõtvaid seadmeid (sisaldasid aktseleromeetrit ning GPS-süsteemi) ning pulsivöösid.

Tulemused: Keskmine üldine treeningkoormus ühe mängu minuti kohta oli kahanev, sõltudes mängu formaadist: 5v5 > 8v8 > 11v11. Keskmine läbitud distants kiirusel >21,0 km/h oli 11v11 võistlusmängus (esimene poolaeg: 4,4±2,5 m; teine: 4,7±2,5 m) statistiliselt oluliselt ($p<0,05$) suurem kui 5v5 mängudes (3,3±3,0 m). 5v5 ja 8v8 üldjuhul ei jäljendanud 11v11 võistlusmängudes tekkivaid MIP-sid. Mängijatel, kes paigutusid YY testi tulemuste põhjal kõrgeimasse sooritusvõime gruppi, esines võrreldes madalaima sooritusvõime grupi mängijatega võistlusmängu ajal suurem väline koormus ning väiksem sisemine reaktsioon väljendatuna 90-100% intensiivsustsoonis viibitud ajana

Kokkuvõte: VM-des esinevad keskmised kehalised nõudmised on mõnevõrra suuremad kui võistlusmängudel, kuid sellele vaatamata ei jäljenda VM võistlusmängule iseloomulikke MIP-sid. Mängijad, kes suudavad YY testis edukamalt esineda, saavutavad võistlusmängus suurema välise koormuse ning kogevad madalamat sisemist reaktsiooni.

Märksõnad: jalgpall, vähendatud mängijate arvu ning väljaku mõõtmetega mängud, treeningkoormus, välise koormuse analüüs, südamelöögisagedus

1. REVIEW OF LITERATURE

Theory about training argues that the specificity of training is one of the most important factors for the coach to consider (DeWeese et al., 2015). To improve the performance of the athlete, requirements of the sport itself should be taken as fundamentals for the training, therefore, training and sport itself should be similar (Woods et al., 2019). Besides technical, psychological and tactical, another dimension of specificity in soccer trainings that coaches should considered are physiological demands.

Different physical and physiological abilities are important for elite soccer players. These abilities include aerobic endurance, speed and power (Hoff, 2005). On elite level, soccer's physical demands, that the game sets for the players, have risen over time (Bush et al., 2015). Nevertheless, this has not been set to human limits as there is evidence that, even in a case of an early dismissal of a player, remaining players can compensate the disadvantage by increasing their running performance, so that the overall team's running performance might not drop (Carling & Bloomfield, 2008). Reilly et al. (2000) suggests that it is not necessary for a player to have the highest possible physical abilities (i.e., maximal oxygen consumption) but abilities just high enough to cope with the demands of the game. For example, they suggested the necessary oxygen consumption to be around 60 ml/kg/min. Furthermore, during a competitive soccer game, the highest sprinting speed that strikers usually reach is around 93.6% of their maximum speed, while central midfielders reach even lower top speeds, around 85.3% (AL Haddad et al., 2015). It can be speculated that soccer's complexity and contextual factors do not require or even prevent players from using their full physical capabilities in competitive matches (Paul et al., 2015; Salvo et al., 2009). Even though physical abilities are important in soccer, the current understanding suggests that the players do not need to have the highest possible levels of abilities, but high enough to cope with the demands of the competitive game and to fulfil their tactical role in the playing scheme (Lacome et al., 2018).

As soccer players do not necessarily need to use their physical abilities like maximum speed and running performance to the highest possible level (Carling & Bloomfield, 2008; AL Haddad et al., 2015; Paul et al., 2015), the need for training these abilities in isolation could be questioned. Successful soccer players need a combination of skills (physical, tactical, psychological and technical), therefore, to get the most of every training, it is preferred that these are developed simultaneously in a soccer-specific environment (Delgado-Bordonau, & Mendez-Villanueva, 2012). Lately, soccer trainings have moved towards simulating game-like situations, exposing players to the complexity of the game itself daily. In consequence, all the required abilities are trained in harmony, not in isolation (Delgado-Bordonau, & Mendez-

Villanueva, 2012; Lacome et al., 2018). Trainings based on different game-like situations are often referred to as "tactical periodization model" (Delgado-Bordonau, & Mendez-Villanueva, 2012).

Small-sided games are common in soccer trainings because they allow coaches to create constraints and use game-like situations which require players to behave in accordance with the complexity of soccer. Small-sided games are soccer games where one or both conditions occur: 1) there are less players on the field than 22; 2) field dimensions are shortened in comparison to a full-size soccer field (Rampinini et al., 2007). This means that small-sided games are a reduced version of a soccer game, considering the court size and the number of players. These games allow coaches to simulate sport-specific technical and tactical demands (Clemente et al., 2014; Hodgson et al., 2014) and to develop soccer-specific fitness simultaneously (Hill-Haas et al., 2009; Impellizzeri et al., 2006).

There has been a lot of research done on the topic of small-sided soccer games (Clemente et al., 2012; Zouhal et al., 2020). Training programmes that include small-sided games have led to an increase in match-related physical abilities (Dellal et al., 2011; Hill-Haas et al., 2009; Owen et al., 2012). Lowering the number of players decreases the teams´ overall amount of ball contacts (Owen et al., 2004). However, increasing the number of players on the field decreases ball contacts per player (Jones & Drust, 2007; Katis & Kellis, 2009; Owen et al., 2004; Rampinini et al., 2007). Consequently, the higher the number of players participating in a game, the less soccer actions will be performed by a player with the ball in an observed timeframe. Small-sided games are a good way to manipulate the overall number of technical soccer actions during training (Clemente et al., 2014). Therefore, game-specific training programmes (small-sided games could be a part of it) have been suggested as a beneficial method in increasing technical abilities (Little, 2009).

The number of players on the field can influence the training load of small-sided soccer games. Changes in training load can be measured as an external (eg, total distance covered; quantity of low- to high-intensity running) and/or internal load (eg, heart rate, blood lactate, rating of perceived exertion) (Köklü et al., 2017). It seems that actions which require more space on the field (sprinting, high-speed running and high-speed accelerations/decelerations) tend to be performed more often in larger game formats (with more players and larger field dimensions) (Lacome et al., 2018) and with the same number of players on the field but with higher relative pitch area per player (Hodgson et al., 2014).

Through altering the relative pitch area (Hodgson et al., 2014), bout duration (Köklü et al., 2017) or the number of players on the field (Clemente et al., 2014; Gaudino et al., 2014;

Rampinini et al., 2007), participants can perceive significantly different training load. It is suggested that when the number of players on the field is reduced, both internal (Köklü et al., 2017; Rampinini et al., 2007; Katis & Kellis, 2009) and external load (Castellano et al., 2013; Gaudino et al., 2014; Köklü et al., 2017; Lacome et al., 2018) increases. To plan and execute trainings, coaches should be aware about the different effects on training load when using alterations in small-sided games (field dimensions, number of players, playing time).

In the "tactical periodisation model" the reference point for planning a single training are the demands of a competitive game (Delgado-Bordonau, & Mendez-Villanueva, 2012). There is some knowledge about the physical demands of the competitive game in professional male soccer (Akenhead et al., 2013; Lacome et al., 2018), but to understand the training load of small-sided games, it should be compared in relative to the demands of the game. Therefore, trainings that consist of small-sided games should be assessed concurrently to competitive games. Lacome et al. (2018) has compared French elite level male competitive games with small-sided games in trainings, but unfortunately, they only reported data concerning external load.

Depending on the size of the field, bout duration and number of players involved, the average heart rate of an adolescent male soccer player during a small-sided game varies between 80-95% of his maximum heart rate (Castellano et al., 2013; Köklü et al., 2017; Katis & Kellis, 2009). In various small-sided games, elite male soccer player covers, on average, approximately 1 to 5 meters/min of high-intensity distance (>19.8 km/h) and 11 to 19 meters/min of high-speed running (>14.4 km/h) (Gaudino et al., 2014). Whereas, in small-sided games between French elite level players, approximately 10 to 40 meters of high-speed running distance per minute was covered, depending on the rolling duration of the game (Lacome et al., 2018). Throughout different small-sided games between semi-professional male soccer players, the similar metric of player load (also used on current study) ranged from 9.7 up to 10.3 in Arbitrary Units (AU) per minute (Castellano et al., 2013).

One way to look at competitive match demands in soccer is through total training load or training load per minute showing the average intensity (Lacome et al., 2018). Another way to examine the training load is through most intensive periods of the activity – worst case scenarios (WCS) (Gabbett, 2015). WCS-s are the moments during an activity where the training load of the player is highest in the observed time frame (Oliva-Lozano et al., 2020). For example, if the soccer game lasts for 90 minutes, then the 5-minute total distance WCS is the 5-minute period in the whole 90-minute game where that particular individual covered the most distance. To assess WCS-s various of workload metrics could be used.

Sport specific trainings are fundamental for improving individuals' performance (Woods et al., 2019). WCS represent most intensive periods of the game and should be considered as part of competitive match demands because when trainings do not simulate these situations then the players are not prepared for the game optimally (Gabbett, 2015). As training environment is not the same as competitive game, it might be difficult to simulate WCS-s during trainings (Gabbett & Mulvey, 2008). Coaches who want to simulate all match demands during trainings should acknowledge the described issue and try to find ways for overcoming it.

There is evidence that performance during endurance test Yo-Yo Intermittent Recovery Test Level 1 (YY test) is related to the high-intensity running distance during a competitive soccer game (Krustrup et al., 2005), therefore, YY test could be considered an useful tool to evaluate match-related physical capability. YY test focuses mainly on high-intensity aerobic running showing an individual´s ability to perform intensive activity repeatedly (Bangsbo et al., 2008). Soccer is not the only sport where match performance correlates to the results of YY test, basketball and handball players who cover more distance during YY test show better game-related endurance performance (Castagna et al., 2008; Souhail et al., 2010). YY test has proven itself as a valid fitness test with high reproducibility between testing days (Krustrup et al., 2003).

2. AIM AND OBJECTIVES

The aim of the present study was to investigate training load during competitive soccer matches and small-sided games played in soccer trainings. Secondly, the interaction of endurance performance to the measured training load parameters was observed during competitive matches in youth soccer players.

The specific objectives of the study were:

1. To assess and compare the average training load during 5 versus 5 (5v5), 8 versus 8 (8v8) small-sided games and 11 versus 11 (11v11) competitive soccer matches.
2. To assess and compare the average training load during 5-minute worst case scenarios while playing different small-sided games (5v5, 8v8) and competitive soccer matches.
3. To measure endurance performance on the Yo-Yo Intermittent Recovery Test Level 1 and to compare the results with the external as well as internal load of the players during competitive soccer matches.
4. To investigate if high-speed related external load is dependent on the endurance performance level of the soccer players.

3. METHODS

3.1. Participants

The participants of this study were 19 male soccer players (age: 17.6±1.1 yrs; body mass: 74.1±8.6 kg; body height 182.4±7.4 cm) who were actively training and competing in the second division (Esiliiga) of the Estonian football league system. Data was collected during routine trainings and competitive league games in the season of 2021. None of the participants were goalkeepers. All participants and the legal guardians of participants younger than 18 years, gave written consent after a full explanation of the study protocol. The Ethics Committee of the University of Tartu approved the study (protocol number: 345/T-17) and the study was performed in accordance with the principles of the Declaration of Helsinki (1975).

3.2. Study overview

All subjects passed a routine visit to the team's physiotherapist, who measured the participants' body mass and height prior to collecting training and match data. Individual maximum heart rates and endurance performances were measured during Yo-Yo Intermittent Recovery Test Level 1. Match data was collected during competitive league matches (n=5). Data came from a total of 33 individual performances in the first half and 28 individual performances in the second half of any match. Data about the activity during the first and the second half was collected separately and was used only if the player played the full half (45 min + extra time). Small-sided game trainings were not done earlier than 72 hours after the match day (Fatouros et al., 2010) and not in consecutive days (Sparkes et al., 2018). Standardized 20 min warm-up was used for trainings where small-sided games were played. All competitive matches and trainings were performed on the same field (natural grass) and with comparable weather conditions. During the matches and the small-sided games subjects were equipped with a Global Positioning System (Catapult Vector X7, Melbourne, Australia) for time-motion analysis. Catabult device was in interaction with a Polar heart rate sensor that was connected to a belt (Polar Electro Oy, Kempele, Finland) strapped around the subject's chest.

3.3. Data collection and measurements

3.3.1. Anthropometric data

Subjects' body height and mass were measured during a regular visit to the team's physiotherapist 24 days before the first small-side game measurement. Height was measured to the nearest 0.5 cm. Body mass was measured with light clothing and without shoes to the nearest 0.1 kg (Beurer 760.30 - BG 13, Ulm, Germany).

3.3.2. Yo-Yo Intermittent Recovery Test Level 1

Yo-Yo Intermittent Recovery Test Level 1 was conducted on a natural grass field after a light football training session to determine the maximum heart rate and endurance performance of the subjects, who wore the same equipment as they did in small-sided games and competitive matches (for details see section 3.5). All subjects started the test simultaneously. After a signal from a speaker, the subjects had to run to a line 20 meters from the starting line, step on the line, run back to over the starting line before the next signal, running a total of 40 meters. Next, the subjects had 10 seconds of active recovery, which meant that the participants had to walk or jog to a line 5 meters from the starting line and back to the starting line (a total of 10 meters) within the recovery period. It was mandatory to come to a full stop before the next run. The time duration between speaker signals of the running phase is linearly decreased after certain repetitions. If a participant failed against any rule of the test (including starting to run too early) he got a yellow card, after the second yellow card the subject was eliminated from the test and the test result for that particular participant was the moment that he got eliminated. All the players had done this test before and, therefore, were familiar with the test procedure. The total distance ran (excluding distance covered during recovery) and maximal heart rate were recorded during the test. Maximal heart rate was used to determine heart rate zones. Individual maximal heart rate zone was calculated as 90-100% of the individual maximal heart rate of the subject. Individual heart rate zones were added to the player’s profile in the Catapult Vector system for the use in data collection in competitive matches and small-sided games.

3.4. Small-sided games

Small-sided games were played according to the regular soccer rules: throw-ins, corners, offside on the opponents’ half, no touch limit. There was always a coach on both sides of the sideline with an extra ball to allow quick throw-ins. Additional balls were also available in both goals. There was no encouragement from coaches during the games. 5v5 games were played in the formation of goalkeeper – 2 defenders – 2 attackers. 8v8 in the formation of goalkeeper – 3 defenders – 3 midfielders - 1 attacker (for reference, 11v11 competitive match formations were mostly goalkeeper - 4 defenders – 2 central midfielders - 3 attackers – 1 striker). The number of players indicated in the game setting (i.e., 5v5, 8v8 or, for reference, 11v11 competitive matches) included the goalkeeper in all games.

Trainings where small-sided games were played, started with soccer-specific warm-up that included mostly different ball possession games. The warm-up session lasted for 20 minutes and players had at least a 3-minute break before the beginning of the first small-sided game. Weather during the events mainly varied from +20 to +25 °C, the pitch was dry during all the activities.

During the training session, only one small-sided game format was played, either 5v5 or 8v8. 5v5 games were played on a field of 48x31 meters (149 m^2 per player). The game was divided into 5 bouts of 5 minutes with 3 minutes of passive recovery between every bout (Table 1). Data about 5v5 small-sided games was collected from 4 separate training days. 8v8 (7 versus 7 (7v7) + 2 goalkeepers) small-sided games data was also collected from 4 separate training days. 8v8 games were played on a field with the dimensions of 76x49 meters (233 m^2 per player) and was divided into 3 bouts of 10 minutes with 3 minutes of passive recovery between every bout (Table 1). Thus, the total active playing time during one training was 25 minutes for 5v5 games and 30 minutes for 8v8 games. With the inclusion of the recovery time, the total durations of the games were 37 and 36 minutes respectively. Data from recovery periods between bouts was not used in training load analyses.

Each subject's performance was measured separately for all small-sided game bouts in which the subject participated for the entire training. In regards of competitive matches, the performance was measured separately for each of the halves of the game (first and second half) and was used for data analysis only if the player played the full duration of the half. During the 4 training days in which 5v5 games were played, individual game performances were recorded of the 19 subjects, creating 210 sets of individual session data. During the 4 training days in which 8v8 games were played, individual game performances were recorded of the 19 subjects, creating 147 sets of individual session data. During the 5 competitive games, 33 individual session performances were recorded of the 19 subjects during the first half of the game and 28 individual session performances during the second half of the game. In cases of incomplete heart rate data recordings of a session, the time-motion data recordings were not disregarded.

Table 1. Overview of the general methodology of data collection during the small-sided and competitive games in youth soccer players

	Competitive games	5v5 small-sided games	8v8 small-sided games
Warm-up	20 minutes	20 minutes	20 minutes
Game duration	2x45 min	5x5 min	3x10 min
Rest between bouts	15 min	3 min (passive recovery)	3 min (passive recovery)
Number of trainings/matches	5	4	4
Field size	104.8x67.7 m (323 m^2 per player)	48x31 m (149 m^2 per player)	76x49 m (233 m^2 per player)
Additional information	Data was used only if the player played the full half of the match	Teams were arranged in a way that the game would be as competitive as possible. The data was used only if the player played all the small-sided game bouts during one training session	

3.5. Training load measures and the used metrics

Players' activity was recorded using a 10-Hz Global Positioning System (Catapult Vector X7, VDS702; manufactured 2020/10 by Catapult Sports, Melbourne, Australia) and analysed using the OpenField Operator Console 3.3.0 (#6614, Melbourne, Australia). Polar H9 heart rate monitors and their elastic electrode belts (Polar Electro Oy, Kempele, Finland) were used to continuously monitor players' heart rate during every training session or competitive match.

Heart rate was recorded as a percentage of time spent in the zone 90-100% of previously determined maximum heart rate (Casamichana & Castellano, 2010). 90-100% heart rate zone was used in current study because it has been observed as the clearest differentiator in regards of heart rate measurements between different small-sided games (Casamichana & Castellano, 2010). Training soccer players in this heart zone (90-100%) has also shown to enhance game-related endurance performance and maximal oxygen uptake (aerobic endurance) (Helgerud et al., 2001; Impellizzeri et al., 2006). Maximum heart rate was set according to the value measured during the YY test. For example, if a player's maximum heart rate was 200 beats/min, the 90-100% zone for that player was calculated as 180-200 beats/min. The OpenField system would automatically calculate the percentage of session's time this player had a heart rate in the 90-100% zone.

For the distance covered, speed zone of >21.0 km/h was used (Asian-Clemente et al., 2022). For the purposes of comparing average distance covered with speed of >21.0 km/h for bouts with different durations, the average distance above the speed of >21.0 km/h ² per minute of a subject in a single bout was calculated.

In terms of accelerations and repetitions, the number of times where the player reached accelerations above 2 m/s^2 were counted (Akenhead et al., 2013). For the purposes of comparing average numbers of accelerations above 2 m/s^2 for sessions with different durations, the average numbers of accelerations above 2 m/s^2 per minute of a subject in a single bout was calculated.

Player load is one of the metrics that was used for measuring external load. The player load value is calculated through the sum of accelerations across all axes of the tri-axial accelerometer during movement, as shown in Figure 1. Player load values correlate well to internal and external load, making it a good method to assess overall soccer-specific training load (Casamichana et al., 2013). The calculation was done automatically by the OpenField system. For the purposes of comparing average player load for sessions with different durations, the average player load per minute of a subject in a single bout was calculated.

$$Plyr.Ld(acc)_{t=n} = \sum_{t=0}^{t=n} \sqrt{((fwd_{t=i+1} - fwd_{t=i})^2 + (side_{t=i+1} - side_{t=i})^2 + (up_{t=i+1} - up_{t=i})^2)}$$

Figure 1. Formula for calculating player load, where fwd: forward acceleration; side: sideways acceleration; up: upwards acceleration; t: time.

WCS-s were defined as the most intensive period of 5 minutes in a competitive game session or a small-sided game bout (Delaney et al., 2017; Reardon et al., 2017). The used program calculated the WCS period (5 min) automatically for every game played (for 5v5, 8v8 small-sided games as well as for both halves of a competitive game separately). During WCS-s, total distance covered (Delaney et al., 2017; Trewin et al., 2018) and player load (Trewin et al., 2018) was monitored. WCS for the total distance covered (5 min of the game where the player travelled the most distance) and player load (5 min of the game where the player had the highest sum of load) might not be recorded at the same time period of the bout.

Percentage of session time spent in the 90-100% heart rate zone, number of accelerations above 2 m/s^2, distance covered at the speed of >21.0 km/h and player load were measured during small-sided and competitive sessions. WCS (5 min) total distance covered, and player load were calculated for every small-sided game and competitive match half.

Heart rate data was eliminated during selection of data if the heart rate belt was not connected properly during the whole course of the activity, which meant that continual graph of heart rate could not be analysed. Every individual heart rate graph of the performance in a small-sided game or competitive match was analysed separately. If the player did not play the whole half of a competitive game or did not participate in all small-sided game bouts during one training, the data was not selected for analysis.

3.7. Statistical analyses

For statistical analyses, Statistical Package for the Social Sciences (SPSS) version 20.0.0 was used. Descriptive parameters (X±SD) were calculated. Additionally, player performance during YY test was divided into three categories depending on the distance covered during the test - low, medium, and high. One-way analysis of variance (ANOVA) and Post Hoc Fisher's Least Significant Difference (LSD) tests were conducted on all variables to test the difference between the game type (small-side game or competition) or subject's performance (low, medium, high). For all the test the significance was set at the level of $p<0.05$.

4. RESULTS

The average performance of the subjects in YY test was 1173.7±306.1 meters and the average maximum heart rate was 195.3±6.6 beats/min.

Average player load per minute in 5v5 games (13.5±2.0 AU) was significantly higher ($p<0.05$) than in 8v8 games (12.1±1.5 AU). Furthermore, in 5v5 games, average player load was significantly higher than the average player load for either half of the 11v11 competitive game (first half: 11.1±1.2 AU and second half: 10.0±1.4 AU). The results correlate for accelerations: the number of high accelerations per minute was in a descending order of 5v5 > 8v8 > 11v11 and the differences between all game types were significant ($p<0.05$) (Table 2).

Percentage of time spent in heart rate zone 90-100% during 5v5 games (70.2±14.7%) was significantly higher ($p<0.05$) than in both halves of 11v11 games (first half: 58.5±16.4% and second half: 52.8±20.7%). There was no statistically significant difference between 8v8 (66.3±20.0%) and 5v5 game formats, but during 8v8 games players spent significantly more time in heart rate zone 90-100% than during second half of the competitive game. (Table 2).

During 5v5 small-sided games, average distance covered per minute (3.3±3.0 m) at speed of >21.0 km/h was significantly lower ($p<0.05$) than during 8v8 games (4.5±3.2 m) and both halves of 11v11 (first: 4.4±2.5 m; second: 4.7±2.5 m). There was no statistically significant difference between 8v8 games and either of the halves of 11v11 competitive games (Table 2).

Average player load during worst case scenarios of both halves of the 11v11 games (69.9±9.3 AU and 65.7±8.2 AU respectively) and of 5v5 small-side games (67.5±10.1 AU) were significantly higher ($p<0.05$) than of 8v8 (58.0±7.5 AU) small-sided games. Average distance covered during WCS was significantly higher for both halves of the 11v11 games (678.2±50.6 m and 655.0±60.6 m respectively) than for 5v5 and 8v8 small-sided games (572.3±55.4 m and 568.8±49.2 m respectively). There was no significant difference between distance covered during WCS-s in 5v5 and 8v8 small-sided games (Table 2).

Table 2. Training load during competitive matches and small-sided games in youth soccer players

Variable	5v5 game	8v8 game	Competition 11v11 first half	Competition 11v11 second half
Average player load per minute (AU)	13.5±2.0	12.1±1.5*	11.1±1.2*#	10.0±1.4*#$
Average number of accelerations >2 m/s² per minute (n)	1.1±0.5	0.8±0.3*	0.6±0.2*#	0.5±0.1*#
Average percent of time in HR of 90-100% (%)	70.2±14.7	66.3±20.0	58.5±16.4*	52.8±20.7*#
Average distance covered above >21.0 km/h per minute (m)	3.3±3.0	4.5±3.2*	4.4±2.5*	4.7±2.5*
Average WCS player load (AU)	67.5±10.1	58.0±7.5*	69.9±9.3#	65.7±8.2#
Average WCS distance covered (m)	572.3±55.4	568.8±49.2	678.2±50.6*#	655.0±60.6*#

* - Statistically significant difference from 5v5 small-sided game; # - statistically significant difference from 8v8 small-sided game; $ - Statistically significant difference from 11v11 first half; WCS - worst case scenario; HR - heart rate; Player load - sum of the accelerations across all axes of the internal tri-axial accelerometer during movement- expressed in arbitrary units (AU).

For the comparison between YY test results and training load in competitive matches the participants were divided into 3 separate groups (low, medium and high) according to the performance (total distance travelled) of the YY test.

Average player load per minute was significantly higher ($p<0.05$) in the highest performance group (11.1±1.2 AU) when compared to the medium performance group (10.1±1.3 AU), but no significant difference was found when compared to the lowest performance group (10.7±1.5 AU) (Table 3).

The number of accelerations >2 m/s^2 per minute and distance covered in meters at >21.0 km/h per minute were significantly higher ($p<0.05$) in the highest performance group (0.8±0.2 repetitions; 6.4±2.7 m respectively) when compared to the low (0.6±0.1 repetitions; 3.4±1.9 m respectively) and medium (0.6±0.1 repetitions; 4.5±1.9 m respectively) performance groups. No significant difference between low and medium groups (Table 3).

The percentage of time spent in the heart rate zone 90-100% was significantly lower ($p<0.05$) in the highest performance group (32.1±15.5%) when compared to lowest performance group (57.4±19.8%). No significant difference was found between medium and highest performance groups (Table 3).

In terms of WCS-s, there were no significant differences between the groups for the 5-minute player load. However, total distance covered during WCS-s was significantly ($p<0.05$) higher in the highest performance group (721.9±27.0 m) when compared to the low (644.8±50.9 m) and medium (649.0±50.4 m) performance groups. There were no significant differences between the low and medium performance groups (Table 3).

Table 3. Comparison of training load in competitive matches between three performance groups based on the result of YY test in youth soccer players

Variable	Low performance group (n=6)	Medium performance group (n=7)	High performance group (n=6)
Average player load per minute (AU)	10.7±1.5	10.1±1.3	11.1±1.2#
Average number of accelerations >2 m/s² per minute (n)	0.6±0.1	0.6±0.1	0.8±0.2*#
Average percent of time in HR of 90-100% (%)	57.4±19.8	45.5±28.1	32.1±15.5*
Average distance covered above >21.0 km/h per minute (m)	3.4±1.9	4.5±1.9	6.4±2.7*#
Average WCS player load (AU)	68.8±9.2	64.7±8.7	70.1±8.1
Average WCS distance covered (m)	644.8±50.9	649.0±50.4	721.9±27.0*#

* - Statistically significant difference from low performance group; # - statistically significant difference from medium performance; WCS - worst case scenario; HR - heart rate; Player load - sum of the accelerations across all axes of the internal tri-axial accelerometer during movement for the measured period- expressed in arbitrary units (AU).; n - number of players in the group.

5. DISCUSSION

The main results of this study were: average overall training load per minute was in a descending order of 5v5 > 8v8 > 11v11; during 11v11 competitive games, distance covered at >21.0 km/h per minute was significantly higher ($p<0.05$) than during 5v5 small-sided games; players who were categorized, based on results in Yo-Yo Intermittent Recovery Test Level 1, in the highest performance group, had higher training load during competitive matches than players in low performance group.

5.1. Differences between average training load in small-sided games and competitive matches

The current thesis was conducted based on Estonian second division league games where the average age of the players was 17.6±1.1 yrs. It is interesting to observe that English Premier Reserve League players, with an average age of 19.3±0.5 yrs, ran distances of 505 ± 209 meters at speeds above 21.0 km/h per minute during the 90 minutes of a competitive game (Akenhead et al., 2013), whereas in the current study, the corresponding distance comes to around 410 meters, which is significantly less. One of the causes for this difference could be that English Premier Reserve League players have, on average, better physical abilities which contribute to capabilities for running at high speeds, than Estonian second division. An alternative cause could be that different styles of play and tactical solutions may alter the physical demands that the game presents to the players (Fernandez-Navarro et al., 2016; Reilly, 2005). Supposedly, English Premier Reserve League is stronger league level than Estonian second division, which could raise the demands of the game (higher tempo, more actions per minute, more sprinting). It should also be considered that the expected physical demands of competitive soccer games have risen in time (Bush et al., 2015). Since Akenhead et al. (2013) did the referred English Premier Reserve League study based on measurements that were obtained a decade ago, then the comparative differences between expected physical demands for English Premier Reserve League and Estonian second division could be even higher.

Hodgson et al. (2014) published a study where they assessed training load of a 5v5 game on different pitch sizes. They used small (30x20 m; 60 m^2 per player), medium (40x30 m; 120 m^2 per player) and large (50x40 m; 200 m^2 per player) field dimensions. Adhering to the beforehand classification, the 48x31 m pitch size used in current study would qualify closest to a medium size field used in Hodgson et al. (2014) paper. In terms of physical demands, they found that medium and large pitch sizes created higher training load in all of the measured movement categories compared to the smallest field.

Clemente et al. (2012) published an overview article about the usefulness of small-sided games for soccer training. This article indicated different research papers regarding small-sided games with pitch sizes that were used in the corresponding studies. Field dimensions in different small-sided game studies were quite similar to the ones used in the current study. The main difference in comparison to current study is related to the length of the playing field. We used rather larger pitch sizes because otherwise the limited space would already reduce possibility of high-speed actions (for example sprinting). It has been found that using small pitch sizes could create a predefined gap for high-speed action requirements compared to 11v11 competitive games (Riboli et al., 2022).

In terms of averages of external load metrics (player load and accelerations per min), a descending order of 5v5 > 8v8 > 11v11 with significant difference ($p<0.05$) between game types could be observed. For the internal load metric (% of time in heart rate 90-100%), differences in the order of 5v5 > 8v8 ($p<0.05$) and 5v5 > 11v11 (second half) ($p<0.05$) were evident, but there was no statistically significant difference between 8v8 and 11v11 game formats. Internal load metric, in current study heart rate, should react to the external load (time-motion characteristics) which is experienced in the game. In the current study, 5v5 small-sided games created an environment in which external load demands were higher than in 8v8 small-sided games and competitive games. As managing external load requires reaction from the human body (internal load), it is understandable, why external and internal load show similar results.

In the current study, 5v5 sessions demonstrated 1.1 ± 0.5 instances of accelerations (>2 m/s^2) per minute, whereas 8v8 sessions and 11v11 games (first half) showed on average 0.8 ± 0.3 and 0.6 ± 0.2 instances respectively. In contrast, a study conducted by Gaudino et al. (2014) followed English Premier League players (26 ± 5 yrs), who demonstrated 2.5 instances of accelerations (>2 m/s^2) per minute in 5v5 small-sided games. Furthermore, 2.25 and 1.75 instances of high accelerations were observed in 8v8 and 11v11 games respectively. However, pitch sizes used for small-sided games in the aforementioned paper were two times smaller in terms of relative area per player compared to the current study.

Smaller pitch dimensions are more inhibiting for players to make more intensive accelerations and decelerations when compared to larger pitch dimensions (Köklü et al., 2017; Lacome et al., 2018). As larger pitch sizes create more space to attack and defend, more high-speed running could be allowed (Hodgson et al., 2014). On the other hand, an opposing argument could be that smaller pitch sizes do not allow players to spend as much energy on high-speed running, and therefore they have more energy for intensive accelerations.

Nevertheless, English Premier League is considered the strongest male soccer league in Europe (UEFA, 2022). Estonian first division is ranked 45th in the same table (UEFA, 2022), thus the soccer-related abilities of players could be considered better in the English Premier League when compared to Estonian second division. Soccer-related abilities meaning that their physical (the ability to do more workload in a certain timeframe) and technical (the ability to move the ball quicker to challenge defenders) abilities are developed to a greater extent. Regardless that Gaudino et al. (2014) demonstrated greater physical demands compared to current study, their data showed the same conclusions – the smaller the game format, the larger the number of changes in direction (5v5 > 8v8 > 10 versus 10; $p<0.001$).

In competitive matches, player load during the second half (10.0±1.4 AU) of the game was significantly ($p<0.05$) lower than during the first half (11.1±1.2 AU). The reason for reduced load could be that the fatigue accumulates and players are physically not as capable as they were during the first half of the game. Lago-Penas et al. (2012) for example found that one of the load indicators, total distance covered, dropped during the second half when compared to the first half. However, they speculated that the cause may instead be the drop of effective playing time (ball in play) during the second half. In the current study, there was no significant difference in the average number of accelerations per minute between the first and the second half, however a small decline could be observed (first half: 0.6±0.2; second half: 0.5±0.1). Internal load metric (percent of time spent in heart rate zone of 90-100%) also demonstrates a small decline after the first half, but shows no significant difference (first half: 58.5±16.4%; second half: 52.8±20.7%). Therefore, during the second half, due to game constraints or physical abilities players might not be able to perform the same workload as they would during the first half.

Langendam et al. (2017) conducted a study where they assessed differences between junior (age: 17.6 ± 0.5 yrs; playing level: Dutch junior first division) and senior (age: 18.7 ± 1.1 yrs; playing level: Dutch third division) soccer players' training load during 5v5 small-sided games. They found that during 4 min bouts, junior players spent about 60% of the time in heart rate zone 90-100%. In the current study, players in a similar age group spent 70.2±14.7% of time in the corresponding heart rate zone. Another shared training load metric between the aforementioned study and this paper, was player load. Average player load per minute, which the Dutch junior players demonstrated, was approximately 7.9 AU (7.7 AU for senior players), whereas subjects of this study showed players loads on average of 13.5±2.0 AU. As players in the current study had significantly higher external load (player load) then a correspondingly higher heart rate response (internal load) is an understandable difference.

Data concerning competitive matches of this research shows that during more than 50% of the whole duration of the game (two halves), players' heart rate was in the zone of 90-100% of their maximum heart rate. Similar measurements concerning competitive matches with elite junior players (age 18.1±0.8 yrs) show that during the first half of the game, approximately 30% of the duration of the game is spent in the zone of 90-100% of the maximum heart rate (Helgerud et al., 2001). It was also shown that 45% of the duration of the session (first half), the players' heart rate is spent in the zone of 85-90%, thus a total of 75% of the duration of the game the players' heart rate is in the zone of 85-100%. Newer findings concerning this age group (Aşçı, 2016) show that during competitive matches players spend on average 38% of the time in heart rate zone 90-100% and 60% of the time in heart rate zone 85-100% of maximum heart rate. The average heart rate during official games is mostly reported in between 85-86% (Aşçı, 2016; Edwards & Clark, 2006; Mohr et al., 2004). Unfortunately, there were no common external load metrics which could be used to create a comparison between the current study to the referred ones (Aşçı, 2016; Helgerud et al., 2001). Therefore, it is possible that external loads measured for the current study were higher and thus facilitated a higher corresponding response in internal load. Alternatively, it is also possible that the players in current study did not recover as quickly between soccer-specific actions (quicker recovery should lower heart rate faster between actions) as players in other studies (Aşçı, 2016; Helgerud et al., 2001), or that the same external loads caused on average higher internal load (raise in heart rate) in response due to comparatively lower endurance capacities of the subjects in current study (see paragraph 5.3). In both of these alternatives, we could conclude that the subjects in this study had lower soccer-specific fitness level.

In regards of heart rate in current study there was not as much data for competitive games as there was for small-sided games. The heart rate belt was not comfortable enough for some players to wear it for 45 minutes straight, so they took it off during the game. Secondly, during longer sessions of the competitive games there was an increased possibility for the belt to lose contact with the body during some instances of the game (mainly duels) and thus corrupting the session data. Thirdly, there were less players playing and also less bouts of competitive matches than in small-sided games (2 bouts in one league game; 3 bouts in one 8v8 game and 5 bouts in one 5v5 game). This restriction applies to all the metrics gathered.

Concerning small-sided games and heart rates of participating players, studies show varied results. For example, research has shown that players in 5v5 games spend approximately 52% of bout duration and, in 7v7 games, approximately 40% of bout duration at the heart rate zone 90-100% (Aşçı, 2016). While in another study (Owen et al., 2011) it was shown that during

4v4 games participants had an average heart rate of 90% (from their maximum), but in 10 versus 10 small-sided games the average heart rate was 81%. Finally, a paper published by Katis & Kellis (2009) compared heart rate responses during 4v4 and 7v7 small-sided games and concluded that participating in 4v4 small-sided games resulted in higher average heart rate values compared to 7v7 games (4v4: 88% and 7v7: 83%). Compared to the current study, all the above-mentioned papers show similar conclusions: the smallest format of small-sided games (5v5) creates higher heart rate response compared to larger games like 7v7 and 11v11. It seems that the less players on the field, the higher the internal load (Aşçı, 2016; Katis & Kellis, 2009; Owen et al., 2011). As internal response (for example heart rate) is supposedly created by locomotive activity (external load), it seems that the less players on the field, the stronger is the response from internal load metric, heart rate. Therefore, less players on the field should also create higher overall external load.

5.2. Worst case scenarios

The most demanding passages of play are also known as worst case scenarios. These are the short intervals of time when the game is physically most demanding for the players (Oliva-Lozano et al., 2020). If coaches want their players to be prepared for these scenarios, then trainings should simulate the conditions for most demanding passages of play (Gabbett, 2015). Worst case scenarios in the current study were assessed for 5-minute periods and with external load parameters (player load and total distance covered). The results concerning different types of games played were different in the cases of WCSs from average external load measurements. Firstly, total distance covered during 5-min worst case scenario intervals was significantly ($p<0.05$) lower in 5v5 and 8v8 formats when compared to 11v11 competitive games. Secondly, player load during worst case scenarios (5 min) was significantly lower in 8v8 small-sided games when compared to 11v11 and 5v5 games.

In regard to this study, it was observed that, from the perspective of total distance travelled, both 5v5 and 8v8 games do not simulate a 5-minute period of a competitive 11v11 game. Furthermore, only the 5v5 small-sided game format creates enough player load during the most demanding 5-min period to simulate competitive match demands, whereas the 8v8 game does not.

Another finding of this study is that the average player load during WCS-s in 5v5 games (67.5±10.1 AU) is significantly ($p<0.05$) higher than during 8v8 games (58.0±7.5 AU) although there is no significant difference in total distance covered during 5-minute WCS-s (5v5: 572.3±55.4 m; 8v8 568.8±49.2 m). This finding could be explained with the fundamental nature of the player load: it is measured as the sum of movements of the tri-axial accelerometer across all of the axes and therefore it is more sensitive to changes in acceleration. Distance covered within a 5-minute timeframe concerns the measurement of accumulated speed per specific direction, not accelerations/decelerations. As there are less players and smaller field size during 5v5 games, compared to 8v8 games, it means that during 5v5 games players are more often directly involved in game situations. Both, smaller spaces and higher involvement in game situations create the need for more changes in direction, raising the demands for accelerations and, therefore, stimulating the player load metric to a greater extent than the metric of total distance travelled.

Gabbett and Mulvey (2008) investigated whether 3 versus 3 or 5v5 small-sided games for elite women soccer players could create sufficient training stimulus to be compared to 11v11 competitive matches. They demonstrated that small-sided games simulate the overall movement patterns for a competitive game but do not simulate the high-intensity, repeated-sprint demands. A similar study was conducted on an elite French male football team throughout two seasons (Lacome et al., 2018). Peak total distance and high-speed distance (>14.4 km/h) during most intensive rolling 15 minutes were presented. It turned out that 5v5, 7v7 and 9 versus 9 small-sided games created lower peak workload than competitive games. These results are similar to the findings in the current study – small-sided games may simulate the overall movement patterns of a competitive game (Gabbett & Mulvey, 2008) but generally do not simulate the most demanding passages of a competitive match (Gabbett & Mulvey, 2008; Lacome et al., 2018). Simulating WCS-s in trainings should need special attention, one way to achieve WCS demands could be to use additional running drills to complement small-sided games. An alternative way of raising external load during small-sided games could be to further intensify the game – for example putting a new ball into the game immediately after one goes out (no throw-in, corner or goal kick) and using verbal encouragement during the game (Rampinini et al., 2007).

5.3. Performance in YY test in reference to training load in competitive games

The current study suggests that physical performance in a competitive game relates to the test results in a YY test. Research on the same topic has shown similar results (Krustrup et al., 2003; Krustrup et al., 2005; Mohr et al., 2003). Krustrup et al. (2005) tested the correlation between distance covered during YY test and match performance (total distance covered and distance covered running with high-intensity) on elite female soccer players. A significant positive correlation ($p<0.05$) between YY test and both match performance metrics was found. Another study by Krustrup et al. (2003) on the same topic was conducted on elite male soccer players. They found that during matches, higher performances concerning meters covered with high-intensity running (>15 km/h) correlated with the player's YY test performance. Therefore, it could be concluded that the YY test could be a good tool to predict physical performance between players in a competitive soccer match.

When comparing YY test results for teams in different male soccer leagues, significant differences could be observed (Deprez et al., 2014; Ingebrigtsen et al., 2012; Mohr et al., 2003). Mohr et al. (2003) studied Italian top-level players, who ran significantly longer distances in the YY test than Danish first division (still professional but not as high level as Italian top-level) players (2260±80 and 2040±60 m respectively). Another statistically significant difference ($p<0.05$) was observed during YY tests between first division and third division players in Norway (Ingebrigtsen et al., 2012). Elite (first division) group players ran on average 2033 ± 416 meters, whereas sub-elite (third division) elite (first division) group players ran on average 1633 ± 476 meters. These studies indicate a correlation between performance in a YY test with the playing level of respective players within the same study, so it could be concluded that professional players (higher level) should run more than amateur players (lower level). Comparing YY test results of different studies can lead to more inconclusive results. For example, amateur male players in Rampinini et al. (2007) paper ran 1986 ± 334 meters in the beginning of the season and 2132 ± 380 meters in the end of the season, thus apparently outperforming Danish first division players (Mohr et al., 2003). As such, results regarding the YY tests should mostly be compared within the same study they were measured in. Some of the differences in results for the players in different studies could be explained with variance in criteria used for ending the test for the participant and the current phase of the season when the testing took place.

For further context, previous studies that include the YY test also have shown that U18-U19 players in Belgian first division ran on average over 2000 meters (Deprez et al., 2012), U18 players in Croatian first division (professional level) ran on average 1800±415 meters (Markovic & Mikulic, 2011), U17 elite level (professional) players ran 2151±373 meters and sub-elite players in the same study ran 1640±475 meters (Deprez et al., 2014). Players in the current study (could be categorised as sub-elite level with average age of 17.6±1.1 yrs) ran on average 1173.7±306.1 meters, which is clearly less than in all previously referred studies (Deprez et al., 2012; Deprez et al., 2014; Markovic & Mikulic, 2011). Possible reasons behind this level of difference could be that participants in the current study have lower levels of endurance to run these distances and, to some extent, a few poor individual performances (the ability of performing maximum effort) could alter the average result of the whole group.

The current study found that players who ran longer distances during the YY test (high performance group) performed significantly ($p<0.05$) more accelerations >2 m/s², covered more distance at speed >21.0 km/h and covered more total distance during the 5 minutes of WCS-s than did players in medium or low YY test performance groups. Players in the high performance group also had significantly higher ($p<0.05$) player load (11.1±1.2 AU) than the medium performance group (10.1±1.3 AU). An interesting finding of this study is that even though external load was higher for high performance group players, the internal load response (% of time spent in heart rate zone 90-100%: 32.1±15.5%) was significantly lower ($p<0.05$) than in the low performance group (% of time spent in heart rate zone 90-100%: 57.4±19.8%). If higher external load created lower internal load response from players in the high performance group, it could be assumed that their level of soccer-specific endurance is superior to the players in the low performance group.

5.4. Strengths and limitations

The strengths of current study were: all the measurements were done on the same field; data from competitive matches, soccer trainings and YY test were used simultaneously in the same study, which creates the possibility to relate the training load to the endurance performance (YY test) of the player. Some limitations can also be indicated: small sample size (19 subjects) and the loss of some heart rate data during the competitive matches. Furthermore, as for the time limitations for the measurements we were only able to use two small-sided game formats (5v5 and 8v8), however all these formats were played for several times, which allowed to create a larger pool of training load data and slightly eliminate the effect of the single game influence on the overall data. Finally, we did not perform position specific analyse (for example midfielders and strikers separately) as the amount of data was too small for position specific analyse. This is also one aspect that should be considered when interpreting the results of the current study.

Accordingly, new research studies should also concentrate on including more small-sided game formats; using additional internal load metric (for example Rating of Perceived Exertion) or include more trainings/games for larger amount of internal load data and use positional analysis.

6. CONCLUSIONS

The following conclusions were made based on this master thesis:

1. Average overall training load per minute was in a descending order of 5v5 > 8v8 > 11v11 and significantly different between the game types in youth soccer players.
2. During 11v11 competitive games, the distance covered at >21.0 km/h per minute was significantly higher ($p<0.05$) than during 5v5 small-sided games.
3. Worst case scenarios during small-sided games played in training conditions (5v5 and 8v8) mostly did not simulate the external load of the worst case scenarios that players experienced during 11v11 competitive matches.
4. Players who were categorized, based on results in Yo-Yo Intermittent Recovery Test Level 1, in the highest aerobic fitness group, had higher training load during competitive matches compared to the players in low performance group.
5. Players who were categorized, based on results in Yo-Yo Intermittent Recovery Test Level 1, in the highest aerobic fitness group, covered significantly ($p<0.05$) more distance per minute at >21.0 km/h during competitive matches than players in low and medium performance groups.

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